Surface Drifter Program

Rick Lumpkin and Silvia Garzoli
NOAA Atlantic Oceanographic and Meteorological Laboratory, Miami, FL

Project Summary

The Surface Drifter Program is AOML's contribution to the Global Drifter Program (GDP), a branch of NOAA's Integrated Ocean Observing System, Global Ocean Observing System (IOOS/GOOS) and a scientific project of the Data Buoy Cooperation Panel (DBCP). The primary goals of this project are to maintain a global 5ºx5º array of Argos-tracked Lagrangian surface drifting buoys to meet the need for an accurate and globally dense set of in-situ observations transmitting in real time for weather forecast, and to provide a data processing system for the scientific use of these data that support short-term (seasonal-to-interannual, "SI") climate predictions as well as climate research. AOML's GDP responsibilities are to: (1) recruit ships and manage drifting buoy deployments around the world using research ships, Volunteer Observation Ships (VOS) and aircraft; (2) insure the data is placed on the Global Telecommunications System (GTS) for distribution to meteorological services everywhere; (3) maintain META files describing each drifter deployed, (4) process the data and archive it at AOML and at MEDS (Canada); (5) develop and distribute data-based products; (6) maintain the GDP website; and (7) maintain liaisons with individual research programs that deploy drifters.

The drifters provide sea surface temperature (SST) and near surface (mixed layer) currents. A subset of the drifters also measures air pressure, winds, subsurface temperatures and salinities. These observations are needed to (a) calibrate SST observations from satellites; (b) initialize global SI forecast models to improve prediction skill; and (c) provide nowcasts of the structure of global surface currents. Secondary objectives of this project are to use the resulting data to increase our understanding of the dynamics of SI variability, and to perform model validation studies, in particular in the Atlantic Ocean. Thus, this project addresses both operational and scientific goals of NOAA's program for building a sustained ocean observing system for climate.

Of particular interest is the data collected in the Tropical and subtropical South Atlantic. Large-scale SST distributions drive the response of the climate in the tropical Atlantic sector, and over land areas as distant as the southern and eastern United States. The variability of the subtropical Atlantic and its interaction with the tropics is far from understood, primarily due to the paucity of data that for years have been mainly collected in the major commercial lanes. The variability of the inter-tropical convergence zone (ITCZ) is highly sensitive to changes in SST gradients within the broader tropical Atlantic region, particularly in the meridional direction south of the tropics and during boreal spring (Kushnir et al., 2003). To better understand this variability, improved SST products must be developed and calibrated/validated with in-situ observations. Starting in 1998, a new component was added to this sustained program to fill existing gaps in the observational network, by deploying additional surface drifters in the tropical and subtropical South Atlantic (30°N to 40°S). The main objective was to accurately describe the basin-scale Atlantic currents system and SST seasonal to interannual variations, and the effects of the variability in the climate of the surrounding areas. During FY06, this grant received additional support to deploy surface drifters in support of the CLIVAR Mode Water Dynamics Experiment

(CLIMODE). The goal of this effort is to resolve eddy fluxes across the Gulf Stream front, where strong interannual variability is poorly simulated in present ocean models. Drifters in support of CLIMODE were deployed primarily from WHOI CLIMODE cruises in November 2005 and January 2006, with a large array of 60 NSF-funded drifters deployed in February through March 2007. CLIMODE is now entering its data analysis phase (2008—2009).

Accomplishments

The global drifter array became the first component of the IOOS that reached completion, with 1250 active drifters in September 2005. This number has since been maintained. During FY07, the drifter array averaged 1259 drifters, with a standard deviation of 32 drifters. The maximum size was 1315 (5 March); the minimum was 1192 (24 September). During the fiscal year, the GDP coordinated worldwide deployments of 1023 drifters, 859 funded by NOAA/OCO; 180 drifters were deployed in the Atlantic between 30ºN and 40ºS. AOML managed observations from 2319 unique drifters during FY07 (this is significantly greater than 1250, as some died while new ones were deployed to maintain ~1250).

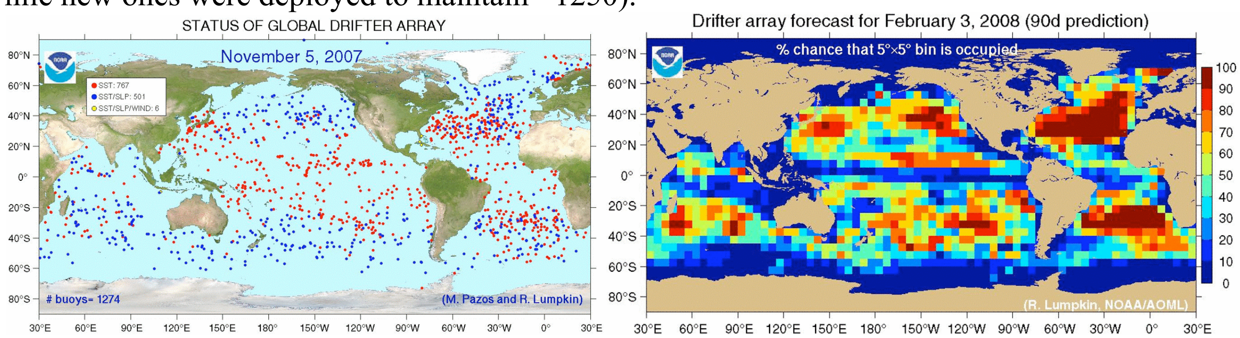


Fig. 1: Global population of drifters as of November 5, 2007 (array size 1274 drifters), and 90 day prediction of coverage (% chance that a 5ºx5º bin will have a drifter if no additional drifters are deployed in the interim).

The main challenge is now to increase the spatial coverage of the array while maintaining its size. We are addressing these challenges by seeking additional deployment platforms and improving our deployment strategies (see FY08 work plan for more details).

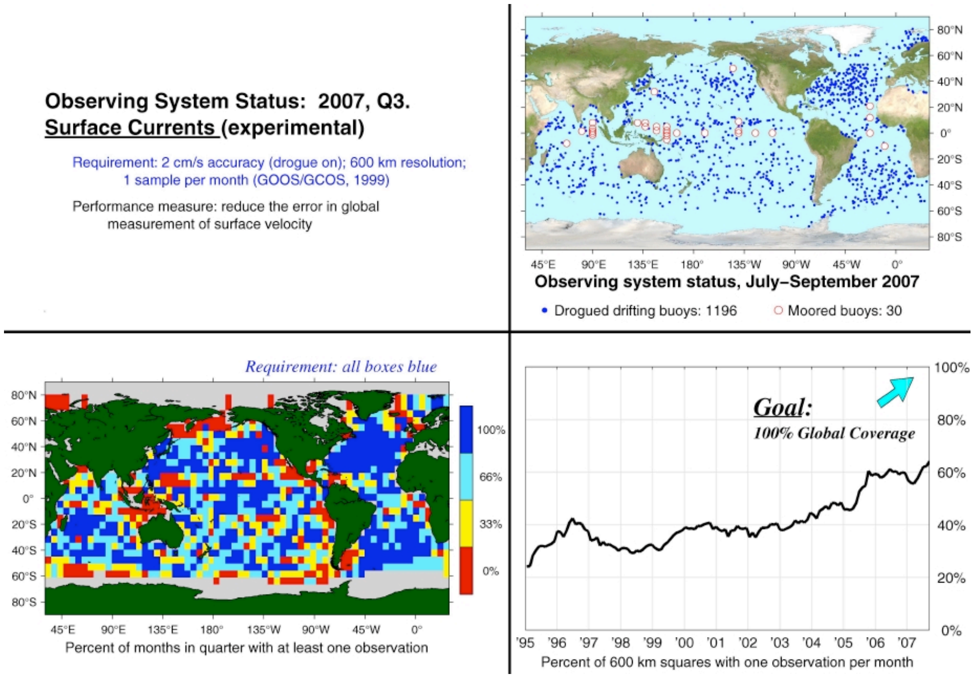


Fig. 2: FY07 Q4 (July-September; Q3 of calendar year) report evaluating the spatial coverage of the IOOS for near surface current measurements. Upper right: location of drifting (blue dots) and moored (bullets) buoys during the quarter. Drifters dominate the overall IOOS' spatial coverage. Lower left: percent of months in quarter with at least one measurement. Lower right: spatial percent of global ocean sampled at GOOS/GCOS requirements.

2007 marks the beginning of the International Polar Year; we have thus placed added emphasis on high-latitude deployment opportunities. Working with Principal Investigator Kjell Orvik (Bergen, Norway), we have had 60 drifters (15 with barometers) deployed off the Norwegian coast in June and October 2007. More deployments are planned for 2008. We will also be increasing the density of deployments off the Antarctic coast in Austral summer 2008, in collaboration with NOAA/NMFS cruises (in addition to ongoing Southern Ocean deployments with other collaborators).

We have also begun working closely with Korean collaborators at several Korean institutions, and with their assistance have seen 17 drifters deployed during FY07. As part of this effort, M. Pazos and S. Dolk of AOML participated in the Ocean and Coastal Observation Panel Meeting convened by Terry Schaefer and Rene Eppi (NOAA/OAR).

In FY07, AOML conducted a general study of the performance of drifters from the four major manufacturers. This study focused on drogue (sea anchor) detection and drifter lifetime. We had previously identified a problem with drogue detection using the submergence sensor, particularly problematic for drifters from one manufacturer (Technocean), and had communicated the problem to them. Although they had implemented an engineering solution (reducing the submergence sensitivity), our FY07 evaluation revealed that the problem was not solved. As a consequence, the Surface Drifter Program is recommending that all manufacturers include a tether strain sensor for drogue detection; we are working with Scripps and the drifter manufacturers to see positive progress on this. We also noted that another of the major manufacturers (Clearwater) was having a large increase in the "death rate" across the array starting in spring 2007 (Fig. 3). The death rate for the other three manufacturers averaged 49—51 drifters dead per 1000 drifters per month, which requires ~750 deployments per year to maintain an array of 1250. The Clearwater death rate increased to a maximum of over 100, which would require >1500 deployments per year. This problem was rapidly communicated to Clearwater, who conducted an in-house evaluation and determined that the problem was most likely due to battery problems. Our ongoing analysis suggests that the problem may have been limited to a specific batch of batteries, as the death rate for Clearwater drifters has been decreasing in the most recent two months.

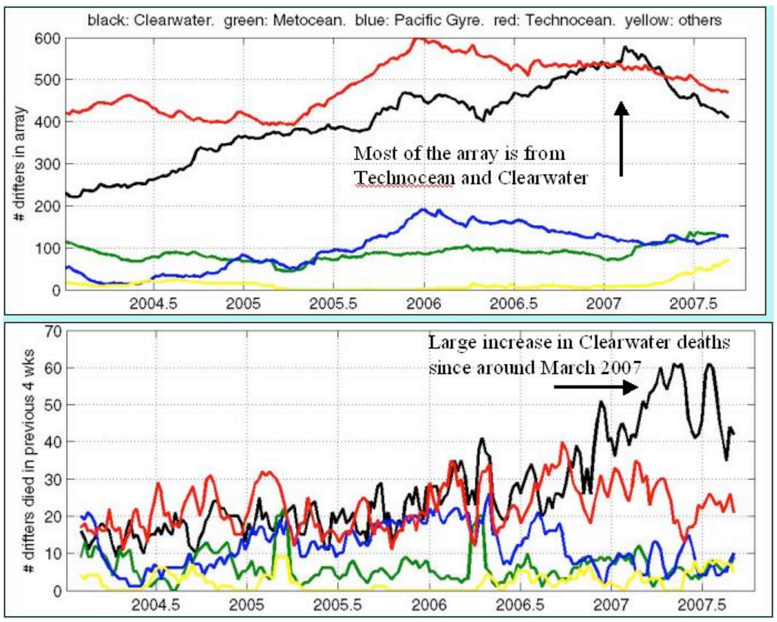


Fig. 3: top: time series of the number of drifters by manufacturer. Two manufacturers, Technocean and Clearwater, manufacture most drifters in the global array. Bottom: numbers of dead drifters per four week period, by manufacturer. The death rate for Clearwater drifters increased in early 2007, and has begun to decline by late 2007.

A subcomponent of the Global Drifter Program, the Atlantic Drifters, was funded with the objectives to fill gaps in the observational network, in order to accurately describe the basin-scale Atlantic current and SST seasonal-to-interannual variations. This program was started to address the data coverage deficiency in the tropical and subtropical south Atlantic (20°N to 40°S). Lumpkin and Garzoli (2005) analyzed the time mean and seasonal variability of the equatorial currents using the resulting drifter data, and shed new light on different branches of the equatorial system and its variability.

The PIs are currently working on the analysis of the data collected in the South Atlantic to characterize the near-surface circulation. Particular focus is on the time-mean pathways of the boundary currents (Confluence of Brazil and Malvinas; the Agulhas/Benguela system) and the variations of the upper ocean exchanges associated with the bifurcation of the South Equatorial Current at the coast of Brazil.

Empirical orthogonal Function (EOF) analysis is applied to the data to define the modes of variability of the basin and at each one of the individual regions. A methodology is developed to locate the Bifurcation of the South Atlantic Current and the Confluence of the Brazil Malvinas Currents with interesting results.

Fig.4 shows the mean surface currents field as derived from the drifter data, superimposed on SST.

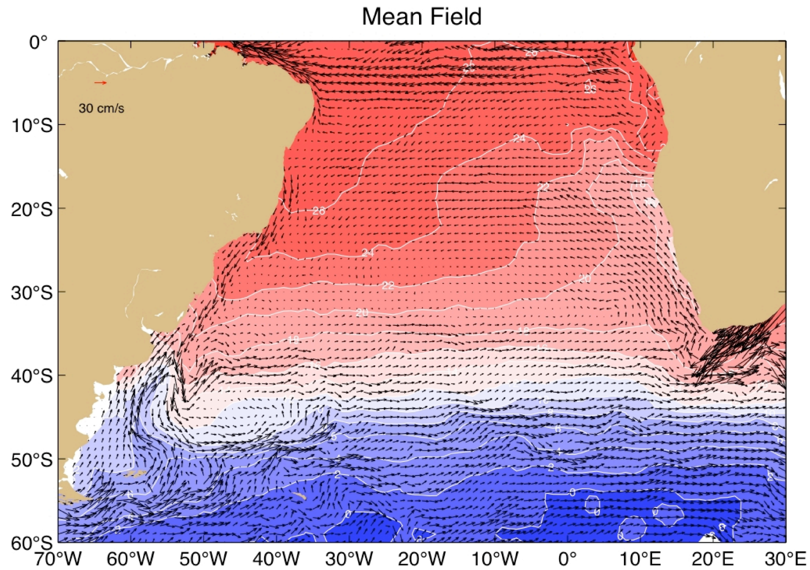
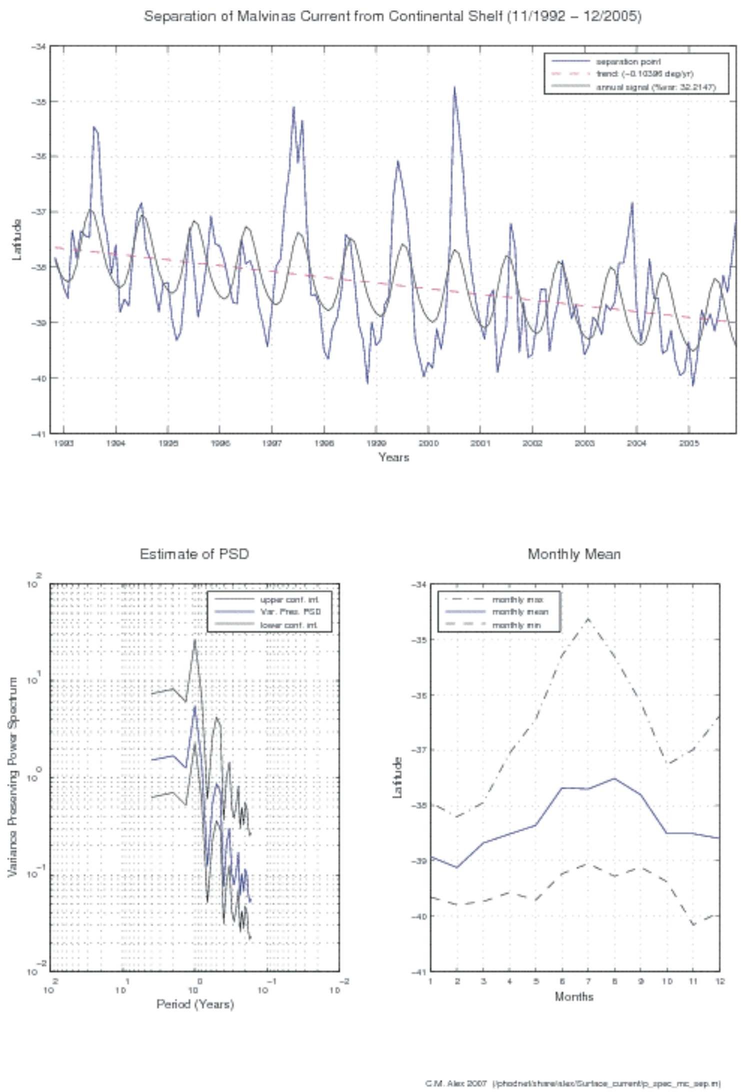


Fig. 4: mean surface currents superimposed on SST

At the western boundary, the bifurcation of the South equatorial Current is clearly seen at around 15°S, and the confluence of the cold and fresh Malvinas Current with the warm and saltier Brazil Current is observed occurring in the mean at 35°S. The eastern boundary is characterized by the Benguela Agulhas system, indicated by the retroflection of the Agulhas Current south of South Africa and the Benguela Current flowing in the north-west direction as a component of the South Atlantic Gyre.

The EOF analysis of the data at the Confluence region indicates a first mode of variability that corresponds to the annual cycle of the Confluence front. The first mode explains 41% of the total variance of the system. During southern hemisphere summer (January-March), the Brazil Current intensifies and reaches its southernmost position. The Malvinas Current concurrently retreats. During Austral winter (June -August) the opposite situation is observed.



The full data set has been analyzed to study the inter-annual variability of the Confluence front as observed by the surface drifters. A methodology is developed to determine the point where the Brazil Current separates from the coast. Results are shown at left. The top panel indicates the latitude of separation for the Brazil Current from the coast. Of interest is the trend that the series indicating that the Confluence front has been moving southward during the last 14 years. This result was also observed from altimeter data for the same period of time and related to an expansion of the subtropical gyre (G. Goni, pers. comm.).

The lower left panel is the spectral analysis of the time series, and the lower right panel the climatology obtained from the time series obtained from the time series after the linear trend is removed.

Overall, the annual cycle is the dominant signal. The percentage of variance explained is lower than climatology (32%), indicating inter-annual variability. A semiannual period is also observed in the spectra.
Similar analyses are being done to study the Bifurcation of the South Equatorial Current and the Benguela/Agulhas system.

Meetings:
R. Lumpkin and M. Pazos (AOML) attended the 22nd Data Buoy Cooperation Panel (DBCP) meeting in La Jolla, California on October 16—20, 2006. There, they presented the results of the 2006 drifter comparison study and the 2006 Global Drifter Program Report, and attended numerous subpanel meetings. M. Pazos attended the June 2007 DBCP Training Course on Buoy Program Implementation and Data Management in Ostend, Belgium. R. Lumpkin attended the August 2007 CLIMODE Principal Investigators' meeting in Massachusetts.

Outreach:
Members of AOML's surface drifter group have given presentations for local groups, and were involved in an episode of the nationally-syndicated "edutainment" children's program "Aqua-

Kids". This episode, aired in October 2007, featured the deployment of several drifters off the Miami coast and an extensive interview with R. Lumpkin about the Drifter Program, NOAA's GOOS, and NOAA's climate monitoring efforts. Lumpkin also authored a chapter of the National Geographic and Smithsonian Institution's "Hidden Depths: Atlas of the Ocean by NOAA" dealing with the subject of ocean circulation, and worked with Smithsonian employees on the "drifters" exhibit for the upcoming Ocean hall of the Natural History museum.

In June 2007, M. Pazos (AOML) helped organize the DBCP Training Course on Buoy Program Implementation and Data Management. This course was developed for collaborators in several African countries and held in Ostend, Belgium. She also taught one of the classes in the course, and developed a training CD that includes information on drifter deployment and data access.

In the last several years, AOML/PhOD scientists (Enfield, Garzoli, Goni, Lumpkin) have participated in cruises conducted from the M/V *Explorer*, a ship operated by Semester at Sea, University of Virginia. During the cruises, our scientists taught the students how to deploy drifters and gave lectures related to the Global Drifter Program and the science conducted with the data collected. We are also participating in a partnership with the US Navy in a Capacity building and partnership program between oceanographic institutions in the US and West Africa. As part of this effort, AOML personnel will train participants in the collection and use of drifter data.

Publications and Reports:

Griffa, A., R. Lumpkin and M. Veneziani, 2007: Cyclonic and anticyclonic motion in the upper ocean. *Geophys. Res. Letters*, accepted.

Lumpkin, R. and M. Pazos, 2007: Measuring surface currents with Surface Velocity Program drifters: the instrument, its data, and some recent results. Chapter 2 of "Lagrangian Analysis and Prediction of Coastal and Ocean Dynamics", ed. A. Griffa, A. D. Kirwan, A. Mariano, T. Özgökmen and T. Rossby, Cambridge University Press.

Lumpkin, R. and G. Goni, 2007: State of the Ocean in 2006: Surface Currents. In "State of the Climate in 2006", ed. A. Arguez, *Bulletin of the American Meteorological Society*, **88** (June).

Lumpkin, R. 2007: Water Movement: Circulation. Chapter in "Hidden Depths: Atlas of the Ocean by NOAA".